Clean copy of allowed claims

1. A reliable symbol identification method for use in a communication system for transmitting symbols of a high order constellation comprising:

estimating decoded symbols from a sequence of captured samples representing a communication signal captured at a receiver,

calculating a reliability factor of a candidate sample from values of a plurality of estimated symbols in proximity to an estimated symbol that corresponds to the candidate sample,

if the reliability factor is less than a predetermined limit, designating the candidate sample as a reliable symbol.

2. The method of claim 1, wherein the reliability factor R of the candidate sample x_n is given by:

$R(x_n) = \sum_{i=-k1, i \neq 0}^{k2} \left| d\hat{}_{n-i} \right| c_i$, where

$d\hat{}_{n-i}$ is an estimated symbol,

K_1, K_2 are number of estimated symbols adjacent to symbol $d\hat{}_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

3. The method of claim 2, wherein $K_1 = 0$.

4. The method of claim 1, wherein the reliability of a two-dimensional candidate sample x_n is given by:

$$R(x_n) = \sum_{i=-k1, i \neq 0}^{k2} (\sqrt{d_1\hat{}_{n-i}{}^2 + d_2\hat{}_{n-i}{}^2})\, c_i \text{ , where}$$

$d_1\hat{}_{n-i}$ and $d_2\hat{}_{n-i}$ respectively represent values of an estimated symbol $d\hat{}_{n-i}$ in first and second dimensions,

K1, K2 are the number of estimated symbols adjacent to symbol $d\hat{}_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

5. The method of claim 1, wherein the estimating comprises:

rescattering the captured samples according to currently known ISI effects, and generating estimated symbols from the rescattered samples according to decision regions of a governing constellation.

6. The method of claim 1, wherein the estimating comprises generating estimated symbols according to a maximum likelihood analysis of conditional probabilities of a captured sample conditioned upon all possible sets of surrounding transmitted symbols and the ranges of all possible ISI coefficients, for all possible values of the captured sample.

7. The method of claim 1, wherein the estimation comprises generating estimated symbols according to trellis decoding based upon all possible sets of surrounding transmitted symbols and the ranges of all possible ISI coefficients, for all possible values of the captured sample.

8. The method of claim 1, wherein the estimating comprises generating estimated symbols according to a maximum likelihood analysis of conditional probabilities of a captured sample conditioned upon all possible sets of surrounding transmitted symbols and the ranges of all possible ISI coefficients, and a uniform distribution of ISI coefficients for all possible values of the captured sample

9. The method of claim 1, wherein the estimation comprises generating estimated symbols according to a maximum likelihood analysis of conditional probabilities of a captured sample conditioned upon past symbol decisions and the ranges of all possible ISI coefficients, for all possible values of the captured sample.

10. A reliable symbol identification method for use in a communication system for transmitting symbols of a high order constellation comprising:

estimating decoded symbols from a sequence of captured samples representing a communication signal captured at a receiver,

calculating a reliability factor of a candidate sample from values of a plurality of decoded symbols in proximity to the candidate sample,

if the reliability factor is less than a predetermined limit, designating the candidate sample as a reliable symbol.

11. The method of claim 10, wherein the reliability factor R of the candidate sample x_n is given by:

$R(x_n) = \sum_{i=-k1, i \neq 0}^{k2} | \hat{d}_{n-i} | c_i$, where

$\hat{d}_{n-i}$ is a decoded symbol,

K_1, K_2 are number of decoded symbols adjacent to symbol $\hat{d}_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

12. The method of claim 11, wherein $K_1 = 0$.

13. The method of claim 10, wherein the reliability of a two-dimensional candidate sample x_n is given by:

$$R(x_n) = \sum_{i=-k1,\, i \neq 0}^{k2} \left(\sqrt{d_1\hat{}_{n-i}{}^2 + d_2\hat{}_{n-i}{}^2}\right) c_i \text{ , where}$$

$d_1\hat{}_{n-i}$ and $d_2\hat{}_{n-i}$ respectively represent values of a decoded symbol $\hat{d}_{n-i}$ in first and second dimensions,

K1, K2 are the number of decoded symbols adjacent to symbol $\hat{d}_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

14. The method of claim 10, wherein the estimation comprises:

rescattering the captured samples according to currently estimated ISI effects, and

generating estimated symbols from the rescattered samples according to decision regions of a governing constellation.

15. The method of claim 10, wherein the estimating comprises generating estimated symbols according to a maximum likelihood analysis of conditional probabilities of

a captured sample conditioned upon all possible sets of surrounding transmitted symbols and the ranges of all possible ISI coefficients, for all possible values of the captured sample.

16. The method of claim 10, wherein the estimating comprises generating estimated symbols according to trellis decoding based upon all possible sets of surrounding transmitted symbols and the ranges of all possible ISI coefficients, for all possible values of the captured sample.

17. The method of claim 10, wherein the estimating comprises generating estimated symbols according to a maximum likelihood analysis of conditional probabilities of a captured sample conditioned upon all possible sets of surrounding transmitted symbols and the ranges of all possible ISI coefficients, and a uniform distribution of ISI coefficients for all possible values of the captured sample

18. The method of claim 10, wherein the estimating comprises generating estimated symbols according to a maximum likelihood analysis of conditional probabilities of a captured sample conditioned upon past symbol decisions and the ranges of all possible ISI coefficients, for all possible values of the captured sample.

19. An equalization method for use in a communication system for transmitting symbols of a high order constellation, comprising:

estimating decoded symbols from captured samples based on a set of ISI coefficient estimates, the captured samples representing a communication signal captured at a receiver, and

revising the ISI coefficients based on the decoded symbols and corresponding received sample values, wherein the contribution of each symbol-sample pair is weighted according to reliability factor of the respective captured sample.

20. The equalization method of claim 19, wherein the weighting of a symbol-sample pair comprises:

comparing the reliability factor of a candidate sample to a threshold, and

assigning a first weight value to the symbol-sample pair if the reliability factor is less than or equal to the threshold, and

otherwise, assigning a second weight value to the symbol-sample pair.

21. The equalization method of claim 19, wherein the weighting of a symbol-sample pair is inversely proportional to the reliability factor of the candidate sample.

22. The equalization method of claim 19, wherein the weighting of a candidate sample comprises:

comparing the reliability factor of the candidate sample to a threshold, and

assigning a first weight value to the symbol-sample pair if the reliability factor is less than or equal to the threshold, and

otherwise, assigning a second weight value to the symbol-sample pair, the second weight being inversely proportional to the reliability factor of the candidate sample.

23. Cancelled.

24. The equalization method of claim 19, wherein the reliability factor of a candidate sample x_n is determined from values of neighboring samples.

25. The equalization method of claim 24, wherein the reliability factor R of a candidate sample x_n is given by:

$$R(x_n) = \sum_{i=-k1,\, i\neq 0}^{k2} | x_{n-i} | c_i \text{, where}$$

x_{n-i} is a value of a surrounding sample,

K_1, K_2 represent numbers of samples adjacent to sample x_n, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

26. The equalization method of claim 24, wherein the reliability factor R of a candidate sample x_n is given by:

$$R(x_n) = \sum_{i=1}^{k} | x_{n-i} | c_i \text{, where}$$

x_{n-i} is a value of a surrounding sample,

K represents a number of samples neighboring to sample x_n, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

27. The equalization method of claim 24, wherein the reliability factor R of a candidate sample x_n is given by:

$$R(x_n) = \sum_{i=-k1, i\neq 0}^{k2} (\sqrt{x1_{n-i}^2 + x2_{n-i}^2})\, c_i \text{, where}$$

$x1_{n-i}$ and $x2_{n-i}$ respectively represent values of a capturedsample x_{n-i} in first second dimensions,

K_1, K_2 represent numbers of samples neighboring to sample x_n, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

28. The method of claim 27 where $K_1 = 0$.

29. The equalization method of claim 19, wherein the reliability factor of a candidate sample x_n is determined from values of estimated symbols $d\^{}_{n-i}$ neighboring the candidate sample.

30. The equalization method of claim 29, wherein the reliability factor R of a candidate sample x_n is given by:

$$R(x_n) = \sum_{i=-k1, i\neq 0}^{k2} \left| d\^{}_{n-i} \right| c_i \text{, where}$$

$d\^{}_{n-i}$ is a value of an estimated symbol,

K_1, K_2 represent numbers of estimated symbols neighboring to symbol $d\^{}_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

31. The equalization method of claim 29, wherein the reliability factor R of a candidate sample x_n is given by:

$R(x_n) = \sum_{i=1}^{k} | d\^_{n-i} | c_i$, where

$d\^_{n-i}$ is a a value of an estimated symbol,

K represents a number of estimated symbols neighboring to symbol $d\^_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

32. The equalization method of claim 29, wherein the reliability factor R of a candidate sample x_n is given by:

$R(x_n) = \sum_{i=-k1, i \neq 0}^{k2} (\sqrt{d_1\^_{n-i}{}^2} + d_2\^_{n-i}{}^2) c_i$, where

$d_1\^_{n-i}$ and $d_2\^_{n-i}$ respectively represent values of an estimated symbol $d\^_{n-i}$ in first and second dimensions,

K1, K2 represent the number of estimated symbols neighboring to symbol $d\^_n$, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

33. The method of claim 32 where $K_1 = 0$.

34. The equalization method of claim 19, wherein the estimating comprises: rescattering the captured samples according to the set of ISI coefficient estimates,

estimating symbols from the rescattered samples according to decision regions of a governing constellation.

35. The equalization method of claim 34, wherein the reliability factor R of a candidate sample x_n is given by:

$R(x_n) = \sum_{i=-k1, i \neq 0}^{k2} | y_{n-i} | c_i$, where

y_{n-i} is a value of a rescattered sample,

K_1, K_2 represent numbers of rescattered samples neighboring to rescattered sample y_n, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

36. The equalization method of claim 34, wherein the reliability factor R of a candidate sample x_n is given by:

$R(x_n) = \sum_{i=1}^{k} | y_{n-i} | c_i$, where

y_{n-i} is a value of a rescattered sample,

K represents a number of rescattered samples neighboring to rescattered sample y_n, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

37. The equalization method of claim 34, wherein the reliability factor R of a candidate sample x_n is given by:

$R(x_n) = \sum_{i=-k1, i \neq 0}^{k2} (\sqrt{y1_{n-i}^2} + y2_{n-i}^2) c_i$, where

$y1_{n-i}$ and $y2_{n-i}$ respectively represent values of a rescattered sample y_{n-i} in first second dimensions,

K_1, K_2 represent numbers of rescattered samples neighboring to rescattered sample y_n, and

c_i is a coefficient representing any prior knowledge of intersymbol interference effects.

38. The equalization method of claim 19, wherein the estimation comprises generating decoded symbols according to a computational approximation of:

$\Pr(x_n \mid h_n{}^k) = \sum_{D(n+k1,\, n-k2)} \int_a [(1/\sqrt{2\pi\sigma^2})\, e^{-(\ldots)2/2\sigma 2}\ \Pr(a) \Pr(D\ (n+k1,\, n-k2))\ ]\ da,$

where

$h_n{}^k$ represents a k^{th} estimate of the captured sample x_n,

k is an index running from a first value - K_1 to a second value K_2, and

$D\ (n+k1,\, n-k2) = \{\ h_{n+k1}, \ldots\ h_{n+1}, h_{n-1}, \ldots\ h_{n-k2}\}$,

σ^2 represents a variance in channel noise, and

$\Pr(a)$ is a probability density function of the ISI coefficients a_i.

39. The equalization method of claim 19, wherein the estimating and the revising operate on captured samples and estimated symbols on a frame-by-frame basis.

40. The equalization method of claim 39, wherein the frames each contain a uniform number of captured samples and estimated symbols.

41. The equalization method of claim 39, further comprising:

designating captured samples as reliable symbols based on the captured samples' reliability factors, and

assembling a frame to include a set of captured samples and a set of reliable symbols from a preceding frame.

42. The equalization method of claim 39, further comprising:

designating captured samples as reliable symbols based on the captured samples' reliability factors, and

assembling a frame to include a set of captured samples and a set of reliable symbols from multiple preceding frames.

43. The equalization method of claim 39, wherein frame lengths vary according to a regular progression of predetermined lengths.

44. An equalizer for use in a communication system for transmitting symbols of a high order constellation, comprising:

a symbol decoder having a first input for captured samples, a second input for estimated ISI coefficients and an output for estimated symbols,

an ISI estimator having a first input coupled to the symbol decoder output, a second input coupled to the first input of the symbol decoder and an output for the estimated ISI coefficients, wherein the ISI estimator estimates ISI coefficients based on the decoded

symbols and corresponding received sample values, each symbol-sample pair being weighted according to reliability factor of the respective captured sample.

45. The equalizer of claim 44, wherein the symbol decoder comprises a subtractive equalizer coupled to a decision unit.

46. The equalizer of claim 44, wherein the symbol decoder comprises a maximum likelihood estimator coupled to a decision unit.

47. The equalizer of claim 46, wherein the maximum likelihood analysis is made having assigned a uniform probability distribution for ISI coefficients over their ranges.

48. The equalizer of claim 46, wherein the maximum likelihood analysis is made having assigned previously decoded symbols to occur with probability equal to one.

49. The equalizer of claim 44, wherein the symbol decoder comprises a trellis decoder coupled to a decision unit.

50. The equalizer of claim 44, wherein the symbol decoder generates decoded symbols according to a computational approximation of:

$$\Pr(x_n \mid h_n^{\ k}) = \sum_{D(n+k1,\, n-k2)} \int_a [(1/\sqrt{2\pi\sigma^2})\ e^{-(\ldots)2/2\sigma 2}\ \Pr(a) \Pr(D\ (n+k1,\ n-k2))\ ]\ da,$$

where

$h_n^{\ k}$ represents a k^{th} estimate of the captured sample x_n,

k is an index running from a first value $-K_1$ to a second value K_2,

$D\ (n+k1, n-k2) = \{ h_{n+k1}, \ldots h_{n+1}, h_{n-1}, \ldots h_{n-k2} \}$,

σ^2 represents a variance in channel noise, and

Pr(a)) is a probability density function of the ISI coefficients a_i.

51. The equalizer of claim 44, further comprising a reliable symbol detector having an input coupled to the first input of the symbol decoder and an output that enables the symbol decoder.

52. A receiver for use in a communication system for transmitting symbols of a high order constellation, comprising:

a demodulator to generate captured samples from a communication signal received via a channel,

a memory system coupled to the demodulator, the memory system logically organized as a captured sample buffer and a decoded symbol buffer, and

a processor coupled to the memory by a communication path, the processor logically organized as a reliable symbol detector, an ISI estimator and a symbol decoder, the reliable symbol detector to identify which of the captured samples are likely to be located within a correct decision region of a constellation notwithstanding ISI effects of the channel, the ISI estimator to estimate the ISI effects based on the symbols so identified by the reliable symbol detector and the symbol decoder to generate decoded symbols from captured samples using estimated ISI effects.

53. The receiver of claim 52, wherein the symbol decoder is embodied as a subtractive equalizer coupled to a decision unit.

54. The receiver of claim 52, wherein the symbol decoder is embodied as a maximum likelihood estimator.

55. The receiver of claim 54, wherein the maximum likelihood estimator assigns a uniform probability distribution for ISI coefficients over their ranges.

56. The receiver of claim 54, wherein the maximum likelihood estimator assigns to occurrence of previously decoded symbols a probability of occurrence equal to one.

57. The receiver of claim 52, wherein the symbol decoder is embodied as a trellis decoder.

58. The receiver of claim 52, wherein the symbol decoder generates decoded symbols according to a computational approximation of:

$$\Pr(x_n \mid h_n^k) = \sum_{D(n+k1,\, n-k2)} \int_a [(1/\sqrt{2}\,\pi\sigma^2)\, e^{-(\ldots)2/2\sigma 2}\ \Pr(a)\Pr(D\,(n+k1,\, n-k2))\,]\, da,$$

where

h_n^k represents a k^{th} estimate of the captured sample x_n,

k is an index running from a first value - K_1 to a second value K_2, and

$D\ (n+k1,\, n-k2) = \{ h_{n+k1}, \ldots h_{n+1}, h_{n-1}, \ldots h_{n-k2}\}$,

σ^2 represents a variance in channel noise, and

Pr(a) is a probability density function of the ISI coefficients a_i.

59. A computer readable medium having instructions stored thereon that, when executed by processing unit, causes a symbol estimation method to be executed in a communication system for transmitting symbols of a high order constellation:

estimating decoded symbols from a sequence of captured samples and a set of estimated ISI coefficients, and

revising the estimated ISI coefficients based on the decoded symbols and corresponding received sample values, wherein a contribution of each symbol-sample pair to the revision is weighted according to reliability factors of the respective captured sample.

60. The medium of claim 59, wherein the weighting of a symbol-sample pair comprises:

comparing the reliability factor of a candidate sample to a threshold, and

assigning a first weight value to the symbol-sample pair if the reliability factor is less than or equal to the threshold, and

otherwise, assigning a second weight value to the symbol-sample pair.

61. The medium of claim 59, wherein the weighting of a symbol-sample pair is inversely proportional to the reliability factor of the candidate sample.

62. The medium of claim 59, wherein the weighting of a candidate sample comprises:

comparing the reliability factor of the candidate sample to a threshold, and

assigning a first weight value to the symbol-sample pair if the reliability factor is less than or equal to the threshold, and

otherwise, assigning a second weight value to the symbol-sample pair, the second weight being is inversely proportional to the reliability factor of the candidate sample.

63. The medium of claim 59, wherein the reliability factor of a candidate sample is determined from values of samples neighboring the candidate sample.

64. The medium of claim 59, wherein the reliability factor of a candidate sample x_n is determined from values of estimated symbols $d\hat{}_{n-i}$ neighboring the n^{th} estimated symbol.

65. The medium of claim 59, wherein the estimating comprises:

rescattering the captured samples according to the set of ISI coefficients,

estimating symbols from the rescattered samples according to decision regions of a governing constellation.

66. The medium of claim 59, wherein the estimating comprises:

rescattering the captured samples according to currently known ISI effects, and

generating estimated symbols from the captured samples according to decision regions of a governing constellation.

67. The medium of claim 59, wherein the estimating comprises generating decoded symbols according to a computational approximation of:

$$\Pr(x_n \mid h_n^k) = \sum_{D(n+k1,\, n-k2)} \int_a [(1/\sqrt{2\pi\sigma^2})\, e^{-(\ldots)2/2\sigma 2}\ \Pr(a)\Pr(D(n+k1,\, n-k2))]\, da,$$

where

h_n^k represents a k^{th} estimate of the captured sample x_n,

k is an index running from a first value - K_1 to a second value K_2,

$D\ (n+k1, n-k2) = \{ h_{n+k1}, \ldots h_{n+1}, h_{n-1}, \ldots h_{n-k2} \}$,

σ^2 represents a variance in channel noise, and

Pr(a) is a probability density function of the ISI coefficients a_i.

68. The medium of claim 59, wherein the estimating and the revising operate on frames of captured samples and estimated symbols on a frame-by-frame basis.

69-72. Cancelled.

73. A framing method for use in a communication system for transmitting symbols of a high order constellation, comprising:

identifying reliable symbols from a first frame of captured samples,

following processing of the first frame, generating a second frame of captured samples, the second frame comprising the reliable symbols from the first frame and a second set of captured samples, wherein the identifying comprises:

estimating decoded symbols from a sequence of captured samples representing a communication signal captured at a receiver,

calculating a reliability factor of a candidate sample from values of a plurality of estimated symbols in proximity to an estimated symbol that corresponds to the candidate sample,

if the reliability factor is less than a predetermined limit, designating the candidate sample as a reliable symbol.

74. The framing method of claim 73, further comprising:

identifying reliable symbols from the second frame of captured samples, and

assembling a third frame from a third set of captured samples and the reliable symbols from the second frame.

75. The framing method of claim 74, wherein the third set also includes reliable symbols from the third frame.